

# **Accurate Simulation of Acoustic Emission Sources in Composite Plates**

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### Abstract

Acoustic emission (AE) signals propagate as the extensional and flexural plate modes in thin composite plates and plate-like geometries such as shells, pipes, and tubes. The relative amplitude of the two modes depends on the directionality of the source motion. For source motions with large out-of-plane components such as delaminations or particle impact, the flexural or bending plate mode dominates the AE signal with only a small extensional mode detected. A signal from such a source is well simulated with the standard pencil lead break (Hsu-Neilsen source) on the surface of the plate. For other sources such as matrix cracking or fiber breakage in which the source motion is primarily in-plane, the resulting AE signal has a large extensional mode component with little or no flexural mode observed. Signals from these type sources can also be simulated with pencil lead breaks. However, the lead must be fractured on the edge of the plate to generate an in-plane source motion rather than on the surface of the plate. In many applications such as testing of pressure vessels and piping or aircraft structures, a free edge is either not available or not in a desired location for simulation of in-plane type sources. In this research, a method was developed which allows the simulation of AE signals with a predominant extensional mode component in composite plates requiring access to only the surface of the plate.

### Introduction

In order to properly configure and calibrate AE instrumentation and sensors, an accurate and reproducible means of simulating AE signals is necessary. This is true for both conventional parameter based instrumentation as well as for full waveform capture and analysis instrumentation. A number of source simulation techniques including pencil lead or glass capillary fractures, pulsed transducers, spark sources, pulsed lasers, and gas jets have been investigated. The pencil lead fracture is probably the most widely used method because of its simplicity, reproducibility, and good time response. A rapid rise time for the simulated source is desired to reproduce the broad bandwidth of signals observed from real AE events. However, the directionality of the source motion is also important for accurate source simulation. This is particularly true for composite plate geometries in which the signals propagate as plate modes [1-3] and where the directionality of the source motion affects the relative amplitudes of the plate modes [4,5]. Since these two plate modes propagate with different velocities, dispersion characteristics, and attenuation behavior, improper simulation of the AE source during calibration can lead to unsound decisions on sensor positioning, erroneous source location, and inaccurate interpretation of test results.

### Experiment

All measurements were performed on a unidirectional 16 ply graphite/epoxy composite plate of lateral dimensions of 0.508 m. along the fibers and 0.381 m. transverse to the fibers (90 degree direction). Waveforms were detected at a distance of 0.1016 m. from the source along the 90 degree propagation direction. Signals were detected with a narrow band resonant sensor (150 KHz resonance with a 100-300 KHz bandpass filter in the preamplifier), which is commonly used in parameter type instrumentation measurements as well as with a broad band transducer. Signals generated by a pencil lead break on the surface of the plate are shown in Fig. 1. The two plate modes, extensional and flexural, are identified in these waveforms. The flexural mode has a larger amplitude due to the out-of-plane direction of the source motion. These calibration waveforms compare well with signals generated by particle impact sources.

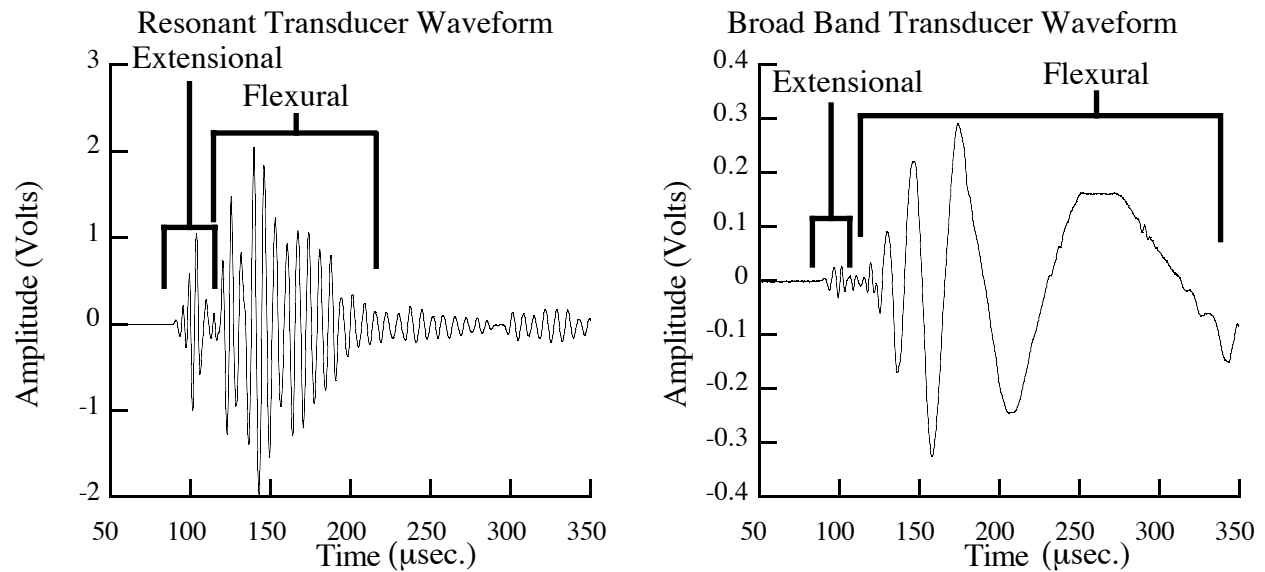


Fig. 1 Signals generated by pencil lead break on the surface of a composite plate which simulates out-of-plane AE sources such as impact and delamination.

In Fig. 2, signals generated by a pencil lead break on the edge of the plate near its midplane are shown. This simulates an in-plane source motion such as fiber breakage or matrix cracking. In this case the flexural mode is nonexistent while the extensional mode has a large amplitude. These signals are similar to those detected from actual transverse matrix cracking events [5].

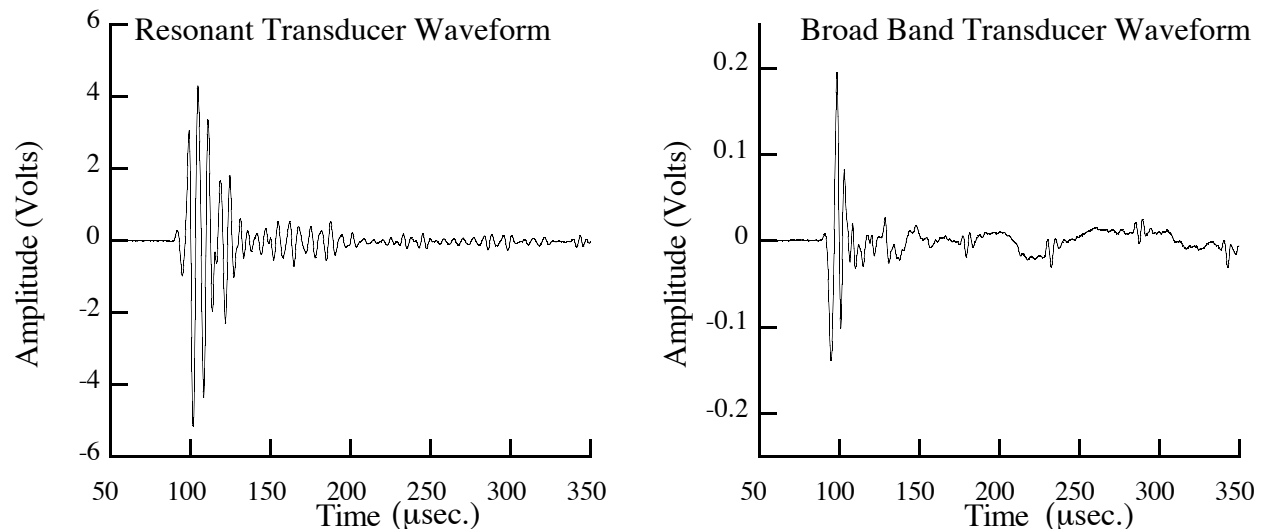


Fig. 2 Signals generated by pencil lead break on the edge of a composite plate which simulates in-plane AE sources such as fiber breakage and matrix cracking.

In testing real structures, however, a free edge may not be available for AE source simulation during calibration. For this situation, a simple technique for in-plane source simulation was developed that required access only to one surface. It consists of acoustically coupling a small cover plate to the surface of the structure of interest. The lead break is then performed on an edge of the cover plate and the resulting extensional mode signal is coupled into the test specimen. The technique is schematically illustrated in Fig. 3. A fixture was manufactured consisting of the cover plate and a structure to hold the mechanical pencil in a precise position with respect to the cover plate to allow ease of use and reproducibility. Also shown in this figure are signals generated using this method. The cover plate was

a square piece of 3.175 mm. thick aluminum with nominal lateral dimensions of 2.9 cm. As desired, this method eliminates the flexural mode. However, when these waveforms are compared to Fig. 2, a couple of differences are noted. First, the extensional mode signal is longer in time. Analysis has shown that this effect is due to multiple reflections within the cover plate which are also transmitted into the structure. It may be possible to lessen or eliminate this effect by placing a damping material along the edges of the cover plate to absorb the wave or by varying its geometry. A second difference is that in this case, the signal generated by this technique is much smaller in amplitude. Further research in aluminum plates indicates that by matching the material properties of the cover plate to that of the structure, more efficient coupling can be obtained.

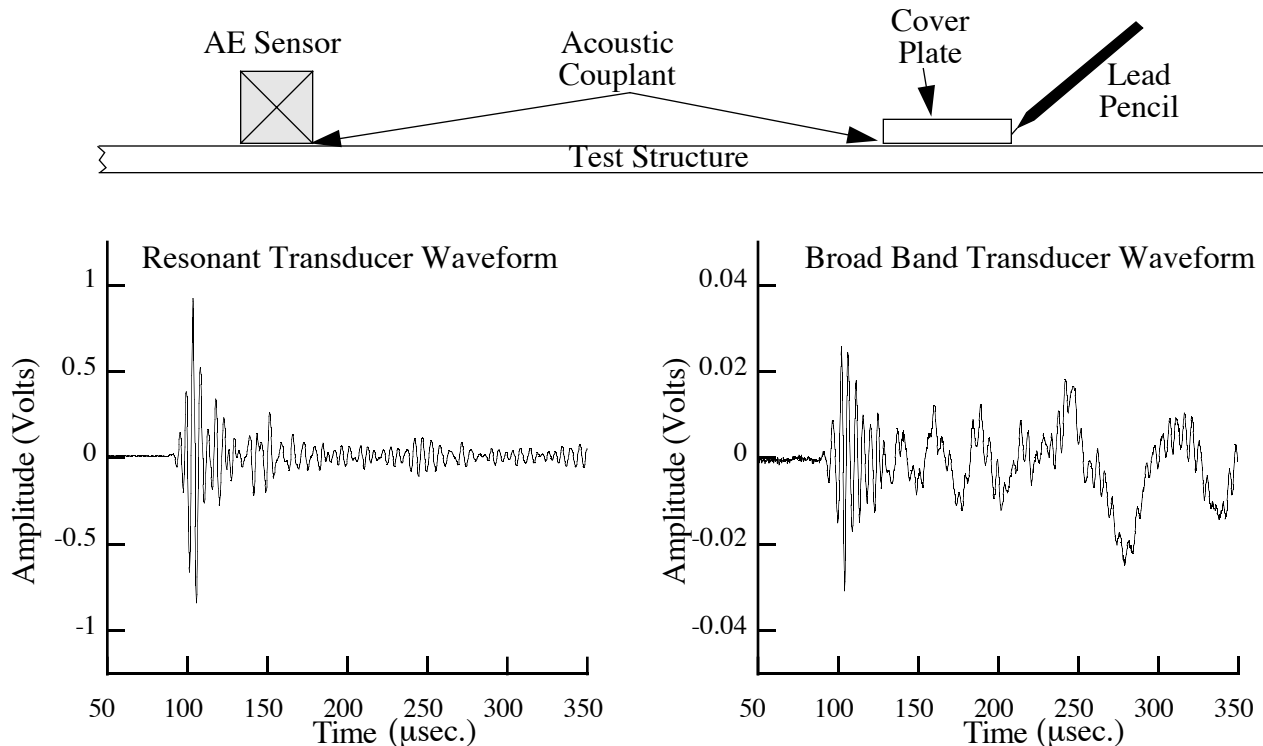


Fig. 3 Schematic of in-plane source simulation technique requiring access only to top of plate specimen and resulting waveforms created with this technique.

### Conclusions

Accurate simulation of AE sources is important for the configuration and calibration of instruments and sensors. Pencil lead breaks can accurately simulate different source mechanisms in composite plates if the directionality of the source motion is considered. A technique was presented which allowed the simulation of an in-plane source requiring access to only the surface unlike a previous method which required a free edge. Future research will focus on analysis of the effects of the geometry of the cover plate, its material properties, and the use of damping materials in order to optimize this technique.

### References

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